Think productivity, Think HSS
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Broaching is a machining operation in which the tool has a linear displacement.

- The tool shape is the same as the part shape and is well suited to producing complex cross sections.
- In broaching, each tooth progressively removes some material, to produce the final shape.
- All operations (roughing, semi-finishing, finishing) are achieved in a single pass.
- Specially recommended for large series, broaching is an alternative technology to milling, boring, turning, grinding and EDM.
- Prerequisite: the surface to broach must be parallel to the direction of tooth travel.
The broaching process is extremely accurate. The efficiency demonstrated in heavy production is unmatched by any other process. Broaching is especially suitable for automotive factories where high efficiency and a high level of accuracy is required.

- **Reduced cycle time**
  Parts are produced in a single pass (usually requiring less than a minute). With other machining processes, multiple operations are required to produce complex and/or irregular shapes.

- **Excellent process accuracy and repeatability**
  Linear displacement means a reduced number of process variables.

- **Superior finish surfaces**
  Fine quality is achieved in just one pass. The last teeth of a broach burnish or hone the pieces.

- **Long tool life**
  Each tooth of the broach contacts the work surface only once per cycle. Therefore a broach can produce a very large number of parts before it needs resharpening.

- **Simplified training and maintenance**
  A broach machine is not complex. In addition, the loading and unloading of parts is easy to automatize.

- **Extremely cost competitive process**
  For high productivity, large batches of pieces can be broached in one pass.
TOOL MAKER’S TIP
Remember that on a broach, the finishing section is larger than the roughing section.
**TOOL MAKER'S TIP**
For large series, boost your productivity with HSS-PM broaches

<table>
<thead>
<tr>
<th></th>
<th>HSS</th>
<th>HSS-E</th>
<th>HSS-PM (powder metallurgy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For easy-to-machine materials such as aluminium, magnesium, free-machining steels (Rm &lt; 800 Mpa)</td>
<td>• For materials such as steels, stainless steels, cast iron (Rm &lt; 1000 Mpa)</td>
<td>• For higher productivity and longer tool life</td>
<td></td>
</tr>
<tr>
<td>Decreasingly used</td>
<td></td>
<td>• For nickel and titanium alloys</td>
<td>• Suitable for dry machining</td>
</tr>
</tbody>
</table>
## TOOL MAKER’S TIP

*For even better performance, combine a coating with a HSS-PM substrate.*

### TiN
- Gold
- Basic choice
- Improved abrasion resistance
- For longer tool life

### TiAlN or TiAlCN
- Black-violet
- For high speed and high productivity, especially in steels
- Also suitable for microlubrication or dry machining

### SUCCESS STORY

**Operation**
- High speed internal broaching with a TiAlN coated HSS-PM broach and microlubrication

**Cutting length**
- 30 mm

**Steel**
- C45

**Benefits compared with machining with a HSS Co broach and oil**
- Cutting speed $\times 10$ ($v_c$ 50 m/min vs. 5 m/min)
- 25% longer tool life
- Better surface roughness
- 15% lower cost per part and lower energy consumption
A BROACH AROUND THE WORLD

French: une broche
German: ein Raumwerkzeug
Italian: una broccia
Spanish: una brocha

VOCABULARY

Shank diameter
Front pilot
First cutting teeth
Semi-finishing teeth
Finishing teeth
Retriever end

Pull end
Front shank length
Roughing teeth
Length of cutting teeth
Overall length
Rear shank length

Front pilot
Rear pilot

Roughing teeth
Semi-finishing teeth
Finishing teeth
Retriever end

Land width
Pitch
Relief angle
Depth of gullet
Tooth radius
Face angle

Tooth Form
TWO BASIC BROACH DESIGNS

Solid broach
The basic choice

Assembly broach
Assembly broaches are composed of several broach segments.
+ Improved accuracy of workpiece
+ Longer tool length compared with solid broaches
+ Complex broach shapes which are not possible with solid broaches
**TOOL MAKER’S TIP**

Broaching is the only solution for producing square holes with sharp angles.

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**Round broaching**

Round broaches are used for high precision holes. There are several types of round broaches: rotary cut broaches used to cut castings without premachining, double cut broaches and burnishing broaches to improve surface finish.

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**Square broaching**

Flat and square broaches are used for producing flat and square holes.

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**Keyway broaching**

Keyway broaches, are widely used, often with a guide bushing that steadies the broach through the process. When the broach is not long enough to cut a high keyway workpiece in one pass, a liner is placed between the broach and the guide. This allows the broach to be pulled two or three times.
Broaching of splines
A spline broach is used to finish cut an involute spline or a straight sided spline.

Involute spline broaches are used in automotive production. They are available with round teeth at the front, or round teeth at the end or, to decrease the eccentricity on the minor and the major diameter of a spline, with alternating spline and round teeth.

Broaching of parallel side splines
Parallel side spline broaches are usually used in track parts or machine part production.

Broaching of serration
A combination broach, with both spline and round teeth, can decrease the eccentricity on the minor and major diameter of a spline.

Broaching of special shapes
Helical splines can also be broached with spiral tooth broaches. The teeth are ground in a helical path around the tool axis. The helix angle corresponds to that required in the work.
TOOL MAKER’S TIP
For mass-production, broaching is a good alternative to milling. Accuracy improves too!

SURFACE BROACHING

Surface broach
- A surface broach is used to remove material from an external surface.
- Surface broaching is usually carried out on a vertical machine with a broach which is either pushed or pulled down.
- The entire length of the broach is usually fixed to the machine.

Surface broach

Example of broached parts
Pull broaching

- Broaching is generally done by pulling.

Push broaching

- When the cutting stock is relatively small, a push broach will be used.
- A pushed broach has a short life span due to rubbing that occurs on the return.
- Push broaching can also be done on a machining center or on a lathe.
Pitch and chip space
- Pitch is determined as a function of the amount of metal removed by one tooth \( t \) (chip thickness). To prevent chips from jamming, the chip space must be 6 times larger than chip volume (Length of cut x chip thickness).

Variable pitch
- To prevent pitch marks on the finished surface, use two or three different pitches of unequal length are used.

Pitch and length of cut
- Pitch \( P = 1.2 \) to \( 2.0 \sqrt{L} \).

Number of engaged teeth
- Normally, several teeth cut simultaneously. Number of engaged cutting teeth = Length of cut/Pitch (should not be a whole number).
**Tool Maker’s Tip**

The chip space must be six times larger than the chip volume.

**Chipbreakers**

Chipbreakers are used on broaches to prevent chip packing and to facilitate chip removal. Without chipbreakers, the broach would produce ring-shaped chips that would wedge in the tooth gullet and eventually cause the tool to break.

Chipbreakers are ground parallel to the tool axis. Chipbreakers on alternate teeth are staggered so that each set of chipbreakers is followed by a cutting edge.

Chipbreakers on a flat broach
Broaches are usually very long tools, from 5xD up to 100xD or more. To avoid any damage during storage, broaches should be hung vertically.

Small broaches

Examples:
Round keyway broach
- Width: 0.4181 mm
- Diameter: 3.175 mm
- Length: 332 mm

Square broach
- Square width: 2.3 mm
- Length: 220 mm

Large broaches

Example:
Internal gear broach
- Diameter: 290 mm
- Length: 2150 mm
TOOL MAKER’S TIP
The choice of pull and retriever ends depends on the type of broaching machine used. Do not forget that the diameters of both ends must be smaller than the pre-broached hole.

**PULL ENDS**

- Cotter
- Jaw/claw
- Threaded
- Pin

**RETRIEVER ENDS**

- Jaw/claw
- Round neck
- Trapezoid
• Cutting speed influences broaching accuracy, the surface of the finished workpiece, and tool life.

<table>
<thead>
<tr>
<th>Workpiece material</th>
<th>HSS broach</th>
<th>HSS Co broach</th>
<th>Coated HSS-PM broach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>3-8</td>
<td>3-10</td>
<td>3-60*</td>
</tr>
<tr>
<td>Stainless steel - tough</td>
<td>2-5</td>
<td>2.5-4</td>
<td>2.5-5</td>
</tr>
<tr>
<td>Stainless steel free machining</td>
<td>4-6</td>
<td>4-8</td>
<td>4-10</td>
</tr>
<tr>
<td>Cast iron</td>
<td>8-10</td>
<td>8-12</td>
<td>8-60*</td>
</tr>
<tr>
<td>Brass</td>
<td>8-10</td>
<td>8-12</td>
<td>8-60*</td>
</tr>
<tr>
<td>Bronze</td>
<td>8-10</td>
<td>8-12</td>
<td>8-60*</td>
</tr>
<tr>
<td>Aluminium</td>
<td>8-10</td>
<td>8-12</td>
<td>8-80*</td>
</tr>
<tr>
<td>Magnesium</td>
<td>8-10</td>
<td>8-12</td>
<td>8-80*</td>
</tr>
</tbody>
</table>

* A special broaching machine is required
Cutting fluids in broaching

• Cooling is essential in broaching. Reducing heat by 50°C can increase tool life by 50%. Poor lubrication can even stop the broaching operation.

• The type of coolant used for broaching will have a large effect on the number of parts broached, accuracy, and efficiency.

• Coolant with low lubrication or low durability will cause cutting teeth to wear faster and, in turn, result in an inferior surface on the finished profile. If the viscosity is too high, chips will get stuck in the broach, lowering efficiency. In general, a higher viscosity is recommended for horizontal machines than for vertical machines.

• Oil is recommended for broaching with low friction additives. Coolant choice also depends on the type of broaching machine.

• Advanced water-based fluids are also increasingly used to improve cooling at high speed or for cutting heat resistant materials. The use of soluble oils is recommended to avoid having to clean parts and to reduce fire hazard.

Minimum Quantity Lubrication

• Microlubrication is also developing.

• Microlubrication makes part cleaning unnecessary and is an environmental-friendly technology.

• Spectacular results can be achieved with TiAlN coatings and HSS-PM steels (see case story on page 6).
<table>
<thead>
<tr>
<th>Problem</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional accuracy (oversized, undersized)</td>
<td>Regrind earlier. Improve coolant flow. Check that there are no burrs on the teeth. Check the dimensional accuracy of the broach. Check workpiece.</td>
</tr>
<tr>
<td>Shape accuracy and position (roundness, run-out)</td>
<td>Check pull end. Check the face angle. Check workpiece clamping and alignment, especially if thin walls. Check the length of cut.</td>
</tr>
<tr>
<td>Rough surface finish</td>
<td>Regrind earlier. Improve coolant flow. Increase speed. Check that there are no burrs on the teeth. Check if vibrations occur.</td>
</tr>
<tr>
<td>Short tool life</td>
<td>Regrind earlier. Improve coolant flow. Use a HSS-PM broach and coatings. Check if vibrations occur. Increase the length of guide.</td>
</tr>
<tr>
<td>Flank wear</td>
<td>Crater wear</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>• Normal wear pattern</td>
<td>• To be limited</td>
</tr>
<tr>
<td>• Decrease the cutting speed ($v_c$)</td>
<td>• Decrease the cutting speed ($v_c$)</td>
</tr>
<tr>
<td>• Use a HSS-PM broach with a coating</td>
<td>• Use a coated broach to stop chemical wear</td>
</tr>
<tr>
<td>• Increase coolant flow</td>
<td>• Check coolant flow</td>
</tr>
</tbody>
</table>

Flank wear Crater wear Deformation
• Estimated load (kN) = width of cut (mm) 
  x cutting depth/tooth (mm) 
  x number of engaged cutting teeth 
  x specific cutting resistance (kN/mm²)

• Safety load (kN) = 1.8 x estimated load

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### Example of calculation

Broaching of a parallel side spline 20 x 16 x 4 x 6SP in alloy steels,

- Length of cut = 25 mm
- Pitch: \(1.5 \times \sqrt{25} = 7.5\) mm
- Number of engaged teeth: \(25/7.5 = 3.4 \rightarrow 4\)
- Cutting depth/tooth: 0.025 mm
- Cutting resistance: 3 kN/mm²

\[
\text{Estimated load} = (4 \times 6) \times 0.025 \times 3 \times 4 = 7.2 \text{ kN}
\]

\[
\text{Safety load} = 1.8 \times 7.2 = 13 \text{ kN}
\]
TOOL MAKER’S TIP

Christmas tree broaches are used to produce the grooves of turbine disks for the aeronautic industry or for the power industry.

Christmas tree broach profile
TOOL MAKER’S TIP
Broaches are very cost effective for mass-production of automotive components.

Broaching of sector gears

Broaching of steering racks

Broaching of connecting rods and disk brakes
Broaching of key holes

Broaches

Key holes